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# **SURGERY OF TUBERCULAR CAVITIES OF THE APEX OF THE LUNG**      ✎      ✎      ✎

Chairman's Address, Delivered Before  
the Section on Surgery and Anatomy,  
at the Fifty-third Annual Meeting of  
American Medical Association, at Sar-  
atoga Springs, N. Y., June 10-13, 1902

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**De Forest Willard, M.D.  
Philadelphia**

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## SURGERY OF TUBERCULAR CAVITIES OF THE APEX OF THE LUNG.

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DE FOREST WILLARD, M.D.  
SURGEON PRESBYTERIAN HOSPITAL.  
PHILADELPHIA.

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When I commenced, a year ago, the experimental work intended to be my contribution to our symposium on "Tuberculosis of the Soft Parts," selected for discussion before this section, it was my hope that I should be able to add something of practical and personal importance to the subject in its relation to human lung surgery. Unfortunately, I am obliged to report that I have been unable to induce any patient to submit to the operation of pneumonectomy or pneumonotomy for tuberculous cavities in the lung. Individuals in the early stages, at the time when operation would be most helpful, have naturally declined it, considering it unnecessarily serious; while those seen by me in the later stages have been too far advanced for me to conscientiously recommend operative procedures.

For many years it has been my expectation and hope that we should be able to treat and eradicate local tuberculosis of the lungs as we eradicate local tuberculosis in the joints and in other tissues. The anatomic and surgical difficulties to be encountered in invasion of the chest are, however, far greater than in any other region, even the brain and abdomen, which must account for the slow advance that has been made in lung surgery. A few brilliant results have been reported, but I regret to say that the majority of operative procedures have

not prolonged life, while in many instances existence has been shortened.

#### OBSTACLES TO OPERATION.

The difficulties in entering the thoracic cavity are due to the fact that respiration is a vital function, which is both important and immediate and which can not be interfered with even for two minutes without serious menace to or even loss of life, while in both abdominal and in cranial surgery the interference is with functions by no means so immediately concerned with existence. The moment that external air pressure of fifteen pounds to the square inch is admitted outside a healthy lung the symptoms of dyspnea in the majority of cases become so profound and alarming that operative procedures must be suspended, and the entire efforts of the surgeon directed to the immediate continuance of respiration. The expansile function of the lungs, the movement of the mediastinal partition of the thoracic walls and of the diaphragm are all concerned, and while the condition is temporarily improved by closure of the wound, yet the air hunger is still great, and unless the Fell O'Dwyer, or other form of artificial or respiratory apparatus is at hand, life may be lost. In a few cases, which can not be explained, these symptoms do not occur either in the human being or in dogs, but they are so rare that the surgeon can not expect to meet them in a given case. Of course, in disease, conditions are different and the admission of air is a less serious matter, the previously compressed lung, or one that is bound to the chest wall, being much less liable to collapse. The anchoring of the lung to the chest wall, either artificially or by disease, not only prevents collapse when air is admitted, but also retains the mediastinal partition in position, and prevents interference with the movements of the opposite lung.

The experiments below enumerated were undertaken in an attempt to discover the possibility of the successful drainage of tubercular cavities in the lung, but it was found that in artificially induced tuberculosis the tendency was to promote general infiltration, and the time required to produce cavities was so long that the experiments were impracticable. I was therefore obliged to content myself with an investigation of the susceptibility of the animal to pneumonectomy and pneumonotomy, together with improvement in the technic of pro-

moting adhesions of the pleural surfaces before making the incision.

It is not my purpose to touch at all on the question of gangrene of the lung, or abscess, or bronchiectasis, or any of the conditions other than tubercular cavities, since time does not permit.

In my experience, even cavities that form in the middle and lower lobes posteriorly are usually the result of previous pneumococic infection, the abscess and the tubercular infection being later results. These are the cases that are almost uniformly successful under pneumonotomy. They should be classified by themselves, since, although sometimes tubercular, they differ decidedly in their prognosis from tubercular cavities in the apex. Many cases of abscess and gangrene following pneumonia in the lower lobe are mistaken for tuberculosis.

#### THE VARIOUS OPERATIONS PERFORMED.

The operations practiced for the relief of tubercular cavities of the lungs are:

1. Compression of the lung by the injection of nitrogen or other sterile gas into the pleural cavity.
2. Removal of ribs to permit collapse of chest wall and consequent compression of lung.
3. Counter-irritation by cautery.
4. Aspiration and the injection of medicated solutions.
5. Incision and drainage of the cavity—pneumonotomy.
6. Excision of the diseased area—pneumonectomy.

#### NITROGEN INJECTIONS.

Compression of the lung by the injection of nitrogen or other gas into the pleural cavity for the purpose of collapsing the lung and thereby giving rest to the organ until healing of the cavity has occurred was advocated by Murphy before the Association in 1898, but statistics are yet too few to form a rational basis for decision as to its merits. Compression of the lung favors fibrosis, cicatrization and occlusion of lymph channels and blood vessels. Lemke<sup>1</sup> has published a number of articles which show excellent results, and he will present further arguments in a paper to be read in the Section on Practice of Medicine at this meeting. His conclusions

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1. THE JOURNAL A. M. A., Oct. 14, 21, 28, 1899.



are that the method is helpful in arresting pulmonary hemorrhage and in hastening cavity cicatrization. His average injection is 120 cu. in. every three or four weeks.

#### COMPRESSION BY REMOVAL OF RIBS.

Allis,<sup>2</sup> Porritt, Ferguson, Berliner, Spengler and others have recommended the compression of the lung and the reduction of lung space by the removal of a portion of the ribs, either in front or behind, or both. The latter adds local treatment by iodoform to the procedure. Bloch immobilized the chest for pulmonary tuberculosis by a plaster jacket on the diseased side, with great relief to the cough and improvement of symptoms.

#### COUNTER-IRRITATION.

Vidal has tried the effect of thorough counter-irritation, treating forty-four cases by the actual cautery applied to the chest wall over the diseased area. He reports thirty-seven good results and believes that the procedure in the early stages is curative, and in the later stages beneficial. He attributes the results to compensatory congestion and to the increased nutrition of the organ called forth reflexly. Cough and expectoration are lessened and general condition improved.

#### INJECTION OF MEDICATION.

Aspiration and the injection of medicated solutions advocated by Baglivi in the 16th century, and practiced by Hastings and Storcks in the 18th, and also by Mosler, was revived by Pepper<sup>3</sup> and others about 1873-4. These injections were used as many as forty times in some cases. They were not unattended by danger, and the results have not been favorable. The substances employed have been iodine 10 per cent., carbolic acid, iodid of potassium, bichlorid of mercury, iodoform, nitrate of silver, etc. Tracheal injections and vapors of creosote, menthol, etc., have also been employed.

#### INCISION AND DRAINAGE.

Pneumonotomy has for several centuries been recognized as among the legitimate operations for attacking cavities in the lungs, notice having first been attracted to its value by the occasional occurrences in duelling, when lung cavities were opened by thrusts of swords.

2. Trans. Penn. State Med. Soc., 1891.

3. Pepper: Trans. Amer. Med. Asso., 1880, xxi, 239.

with recovery following. The operation was done with definite surgical purpose as far back as 1643 by Baglivi, and has been revived at periods since that time, as the tables appended to this report show. Valuable work has been done in this country by Park, Wills, Murphy and others. The percentage of cures does not show any marked increase over those treated along hygienic and dietetic lines. There is no question but that certain cases are markedly benefited temporarily, especially where the infection is mixed, and where both tubercular and streptococcal infections were present in cavities draining imperfectly through the bronchi. The retained secretions rapidly infect the individual and produce those symptoms familiarly known as hectic. The greatest advantage of the operation would be secured by early drainage, but, as stated at the beginning of my article, these are the cases which decline the operation, and in whom also the surgeon is loath to urge its performance. In the later stages there is, of course, far less benefit to be expected, as it is hardly probable that the focus is single, or that the entire diseased area can be reached. In these cases, however, marked benefit does occur from the lessening of the cough and the lowering of the temperature, and the increased comfort and strength given to the patient.

The important preliminary step is the accurate locating of the cavity by auscultation, percussion and the use of the *x*-ray. This latter, while of value, is not positive, and benefit to diagnosis is relative. It is not a certain guide; nevertheless, it is of advantage, as it sometimes gives a shadow at the site of the focus.

#### TECHNIC OF PNEUMOTOMY.

Chloroform is the best anesthetic and need be given but in small amount; in fact, after the external tissues are divided, but little pain will be experienced. Some patients who bear pain well will get on admirably with local anesthesia. An incision should be made from the sternum outward in the line of the second interspace, or over the accurately located diseased focus. As a rule, it is better to excise a couple of inches of one or two ribs, which should be done cautiously and subperiosteally, so that the pleura is uninjured. Some operators go directly through the interosseous space and omit the rib resection, but unless the surgeon is certain that adhesions exist, it is best to have good room for manipu-

lation. After resection, it is sometimes possible to observe through this intervening membrane the movements of the lung, and to determine the very important question of adhesions; upon these adhesions will depend largely the success of the operation. If the cavity can be reached without the admission of air into the pleura, and without the risk of infecting the pleura with the tubercular discharge, two very positive advantages have been secured and the operation becomes a simple one, practically little more than the opening of an abscess. If the pleura is thin, transparent and lustrous, the lung is not adherent; if dense and gray, the layers are probably in contact. An aspirating needle can now be introduced; if the point of the needle moves but slightly, adhesions are present. Murphy has advised the injection of sterile air or nitrogen into the pleural cavity; if there are no adhesions, each inspiration will suck in more air, and the lung will collapse, while if adhesions exist, the respiratory conditions will not change. Shapenko uses an exploratory needle connected with a manometer; if the needle enters an open space, the register is lowered; if there are cavities, it remains stationary. If adhesions are not present, it is always well to delay the operation and endeavor to secure the apposition of the two pleural layers. This I have been able to accomplish in twenty-four hours by carrying catgut sutures with a handled perineal needle, long and with a sharp curve, through the interosseous space, and through the superficial portion of the lung for an inch and a half or more. Four sutures are thus placed in a parallelogram, say one and a half inches wide by two inches long. They are then tied just sufficiently firmly to bring the two layers of the pleura in apposition, but not to strangulate the tissues. In my experience twenty-four to forty-eight hours are long enough to secure adhesions. Chlorid of zinc applied by tampon or by paste is sometimes employed to produce adhesions, but is slow in action. Agar-agar has also been injected into the pleural cavity to fix the lung and produce a new cell formation like connective tissue.

I have never had an accident by the suturing method except once in experimental work, when the needle evidently passed through a good-sized pulmonary vein and then through a bronchiole. The dog collapsed, showed bloody expectoration and died immediately. The postmortem showed that the bronchioles were filled with



blood and the heart with air. This accident adds another to the dangers already reported.

Fortunately, in tubercular cases the lung is usually adherent. If the lung is not adherent, there is danger of pneumothorax and empyema, both of which conditions are exceedingly grave. The wound being left open, the operation may be completed on the second or third day under cocain by an incision along the center of the parallelogram. An aspirating needle may be introduced to find the cavity, the incision being then made along the canula as a guide, either with knife or cautery, according to the choice of the surgeon. If the cavity is deep, of course the latter is less likely to produce hemorrhage from intervening vessels, especially if the lung tissues are soft.

Palpation of the lung substance may discover the site of the abscess, if the aspirator has not been successful, and the finger or a pair of blunt forceps may be used to reach the cavity. Great care must be exercised not to break up pleural adhesions. Once the pus is reached the canal can be dilated by a pair of strong forceps or the finger, and the cavity thoroughly mopped, not irrigated. As there is usually sufficient irritation arising from the operation, it is not well to apply any caustic or any other application to the wall of the abscess. Should a hemorrhage be started, the part should be closely packed with sterile aristolated gauze, which may remain in place for forty-eight hours. If hemorrhage is not severe a rubber or gauze drain may be at once inserted. Irrigations are inadvisable, as material may be carried into the other bronchi, increasing the danger of bronchopneumonia. Where a considerable depth of lung tissue has been perforated in order to reach the abscess, it is well to mop the fresh area with chlorid of zinc solution, five grains to the ounce, in order to prevent fresh infection of lymph spaces from the pus. There will be a slight rise in temperature for a few days after the operation and cough will be increased.

To prevent atelectasis or collapse of the lung, sterile water or air may be slowly injected in advance into the pleural cavity. If collapse occurs the opening may be hastily closed by tamponing with gauze or the finger, and intrapulmonary pressure increased by an artificial respiration apparatus. The lung also may be grasped, brought into the wound and fixed with sutures.

The leakage of air into the pleural cavity from a bronchus that has been opened by ulceration is not as serious in the production of pneumothorax as is the case in a fresh wound of the bronchus. This is well illustrated by a series of experiments that I have reported,<sup>4</sup> where, after an incision of the bronchus, the efforts at respiration after the closure of the wound tended constantly to increase the quantity of air outside the lung, its re-entrance into the air passages being prevented by valve action due to the tubular shape of the bronchus. In a wound of the bronchus, moreover, increased intrapulmonary pressure by a Fell O'Dwyer or other respiratory apparatus would tend to increase the pneumothorax.

Wills<sup>5</sup> has operated on two cases of lower lobe abscess. The first man had had pleurisy, and presented signs of a cavity in the left lower lobe posteriorly below the scapula. Also showed signs of consolidation at apex. Each morning vomited a pint of pus; had night sweats, tubercle bacilli and elastic fibers were found microscopically. The sixth rib was excised in the anterior axillary line, where there was redness and signs of pointing. On opening the pleural cavity the patient collapsed, and the operation was obliged to be suspended. A drainage tube was placed in the pleural cavity. On the ninth day the abscess burst, and fetid gangrenous pus poured from the wound and through an opening in the bronchus. The wound was drained and the man sent into a healthy mountainous region. In five months cough and expectoration ceased; twenty months afterward no sign of abscess, was working hard, and gained seventy-five pounds; has since continued well and strong. This was one of the class of cases which I have already enumerated as being more hopeful than cavities of the apex.

Wills' second case had had pleurisy twice. Cavity in right lung posteriorly. Tubercle bacilli found in sputum. Two inches of the eighth and ninth ribs were excised posteriorly. There was partial adhesion of two layers of the pleura, but no pus in the pleural cavity. Wills<sup>6</sup> speaks very favorably of his result in the first case, and advises the operation, especially when septic

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4. Trans. Amer. Surg. Assoc., 1891, ix, p. 345; also, Amer. Jour. Med. Sciences, December, 1891.

5. THE JOURNAL A. M. A., Jan. 5, 1901, p. 19.

6. THE JOURNAL A. M. A., Jan. 5, 1901.

symptoms are due to imperfect drainage through the bronchi. He believes that it is good, conservative surgery, saving life and giving comfort. Porritt advises that the cavity of the apex be reached from behind, not in front, incision being made above the scapula and portions of the second and third ribs resected. In 50 tuberculous autopsies at the Philadelphia hospital, the adhesions were found both in front and behind the apex in 33 cases; in front, 10; behind, 7. Tuffier, who has had experience with pneumonotomy, considers the dangers great when there are no adhesions, and has been compelled by pneumothorax to abandon his operations in 8 cases; 2 died immediately; in 2 the focus was not reached; one recovered from the operation, and was again subjected to operation two months later; in only one case was the focus reached at the time of operation. Sonnenburg from his experience also emphasizes the dangers both from pneumothorax and from hemorrhage.

#### EXCISION OR PNEUMONECTOMY.

Excision of a portion or the whole of the lung has been successfully tried, both experimentally and in the human subject. Tuffier reports a successful case of removal of a consolidated apex, with the patient living four years later in good health. Doyen and Lowson also report successful cases. Ferguson operated on one patient three times: first, opened abscess; second, excised ribs; third, pneumonectomy; final result, apparent cure. Ruggi also had 2 cases, both died. Hofnobl records 5 cases of pneumonectomy, the apex removed in two cases; both died quickly. Bloch<sup>7</sup> excised at one operation both tubercular apices. The patient died on the table and Bloch, being censured by the coroner, committed suicide.

The chief dangers are pneumothorax, hemorrhage and the tearing of other thoracic organs. If there are no adhesions, the lung must be quickly grasped, drawn into the opening and sutured around the margin.

My own experiments, detailed in this paper and in other places,<sup>8</sup> as well as those of many others, show that considerable portions or even the entire lung may be excised, ligated, cut or cauterized off, and the stump returned to the cavity without serious injury to the animal, but unless the operations are done with thoroughly

7. Walton: Boston Med. and Surg. Jour., 1883, cviii, 261.

8. Willard: Univ. Med. Mag., 1892, p. 333; Trans. Phil. Coll. Phys., xiii, p. 133.

antiseptic precautions, gangrene or empyema are likely to result. A dog is so likely to die under anesthesia, and pneumothorax is so serious a condition with his defective mediastinum, that the best technic seems to be a rapid incision after resection of the ribs, then grasp and drag the lung into the opening, stitch the pleura and lung with catgut, ligate firmly, put in a catgut drain, suture the skin, cover with sterile gauze and apply plaster of paris girdle. By this method the stump in the lung will heal in the wound without pleurisy, and the remainder of the lung will remain active, as the pneumothorax is relieved.

Rabbits have survived completely after excision of an entire lung; human beings doubtless would not. Wills<sup>9</sup> did ten pneumonectomies on rabbits, most of them suffering but little from the operation. Zaharowitch also had fair results, as did Patek and Sailer. Biondi performed pneumonectomies on sixty-three animals, all of which recovered after excision, and Ricketts has had excellent results in his many experiments covering the whole field of lung surgery.

#### STATISTICS OF PNEUMONECTOMY.

Salomoni reports 2 favorable cases; one lived four years, dying of tubercular peritonitis; another two years, death from tubercular meningitis. He records 38 pneumonotomies for tuberculosis; 28 cured. 8 deaths, 2 doubtful. De Cérenville 4 cases of pneumonotomy; 3 deaths. Poirier and Jonnesco in the Paris Congress of Tuberculosis, 1891, reported 29 cases of incision and drainage of tubercular apices; 4 cured. 15 improved. 9 deaths, 1 unknown. Sonnenburg 4 operations. 1 cure, 3 deaths. Hofmohl 5 pneumonectomies. Kronlein 2 pneumonectomies. Groux of Brussels is reported by Bouchout to have had 13 pneumonotomies many years ago. Heydweiller collected 42 cases: 23 deaths, 15 improved, 4 relative cures, 45 per cent. recoveries. Ricketts' collection shows after operation in tubercular cases 60 per cent. recoveries, indicating that surgery of the lung is beneficial. Trzebieky's collection of 24 operations on tubercular cavities gives 5 complete cures (1 living three years after operation), 5 not healed, 9 deaths, 5 results not known. Tuffier, 8 cases pneumonotomy; 2 died immediately, 1 in a few hours, in 2 the focus was

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<sup>9</sup>. THE JOURNAL A. M. A., 1893, August 26, p. 296; also Southern Cal. Pract., Los Angeles, 1892, vii, 167.



not reached, 1 recovered, focus opened four months later, and in one only was the focus reached at the time of operation. He collected 26 pneumonotomies for tubercular cavities; 13 recoveries, 13 deaths; 50 per cent. recoveries. Pneumonectomy, 1 death, puncture 1 case, 1 recovery. Thoracoplasty 3 cases; 2 recoveries, 1 death. Incision of additional abscesses, 5 operations; 4 recoveries, 1 death. Total, 36 cases; 20 recoveries, 16 deaths. Tuffier in his address at the Moscow congress records 306 pneumonotomies for all forms of lung abscess, chiefly gangrene; 217 cured, 88 died, 71 per cent. recoveries.<sup>10</sup> Murphy's<sup>11</sup> statistics show 47 cases of tuberculosis operated on; 34 incision and drainage, 2 pneumonectomies, thoracoplasty 5, opening of superficial abscess 4, puncture and drainage 2; recoveries 26, recoveries with fistula 2, deaths 19.

#### OPINIONS OF WRITERS.

The following condensed opinions of various authors and operators have been collected:<sup>12</sup>

JACOBSON.—Pneumonotomy and pneumonectomy for tubercular cavities have been attended with results so unsatisfactory that they can not be recommended unless possibly under very exceptional circumstances.

KOENIG.—To perform such an operation the surgeon must ignore absolutely all his knowledge of pathology. (Peyrot.)

KEYES.—In tuberculosis the wide distribution of the lesions and general conditions forbid any operative interference.

GODLEE.—Tubercular cavities should not be opened except in cases where the cough is harassing and the cavities single.

BOUCHOUT.—Surgical treatment is contraindicated in tubercle.

BIONDI.—Occasional cases of phthisis may be saved from death by operation.

WARREN-GOULD.—Pneumonotomy for tubercular cavities has not yielded favorable results, as the cavities are usually multiple. When the tuberculosis is advanced sufficiently to justify operation it is rarely limited to the apex only. In the early stage, which is the

10. Tuffier: *THE JOURNAL A. M. A.*, 1898, xxx, p. 169.

11. *THE JOURNAL A. M. A.*, vol. xxxi, pp. 151 and 346: also Syllabus, published in 1898, p. 11, and Reprint, p. 54.

12. From the original articles by Dr. Eugene Lindauer.



only time when total removal is possible, diagnosis is uncertain, and we can not expect, therefore, that the operation will be found applicable in many cases.

POWELL.—Pneumonotomy offers but little hope, as the cavity is not often single.

DANDRIDGE.—The fact that the removal of the local tubercular lesion does not necessarily relieve the system makes the operation uncertain in its benefits.

YEO.—Temporary benefit is about all that can be expected.

MOSLER.—Tubercular cavities should not be opened by the surgeon until an antiseptic is discovered which will destroy tubercle bacilli. Although the operation is possible, it should be employed only in exceptional cases.

TAUFERT.—Operation is inadvisable on account of the liability to hemorrhage, the dangers of pneumothorax and its uselessness.

BERLINER.—Pneumonectomy is to be condemned.

KOCHER.—Surgery in apical pulmonary tuberculosis is questionable because of the presence of tuberculosis in other parts of the lung.

QUINCKE.—Pneumonotomy is a dangerous operation.

RECLUS.—Pneumonectomy for tuberculosis is to be condemned. If the disease is extensive the patient is too far gone, and if the disease is circumscribed medical measures are as good and much safer. Statistics are not wholly reliable, as recoveries are more likely to be published than deaths.

RUGGI.—Tuberculosis of the lungs is beyond the surgeon's interference.

QUENU.—Pulmonary surgery in tuberculosis is usually unsuccessful.

DE CERENVILLE.—Operation dangerous. Five deaths in six cases.

HAHN.—Operation is unsatisfactory.

PORRITT.—The treatment of tubercular lesions of the lung by drainage is an attempt to attain that which with few exceptions has thus far proved to be the unattainable.

VERNEUIL.—Operation is justified only in a few cases, where there is a single focus and the condition good. The abscess wall should be cauterized.

HUGHES BENNETT.—Operative interference in phthisical cavities has been a uniform failure.

TABLES (carefully prepared for me from the original publications by Dr. Eugene Lindauer).

50	Michaux: Ibid. . . . .	Female, 25	Tubercular cavity . . . . .	Signs of a cavity . . . . .	Yes	Similar operation; eighth and ninth ribs removed; cavity not found.	Death four weeks later, due to extension of disease.	Cavity in lower lobe; disseminated tuberculosis.
51	Salomoni: Clin. Chirur. Milano, 1895, p. 65.	Male, 34	Tuberculosis of left lung. . . . .	Symp. of mixed infec.; no signs of a cavity.	Yes	Fifth, sixth, seventh, eighth and ninth ribs resect.; pneumotomy. Sutured two layers of pleura to prevent pneumothorax; excision of wound closed without drainage.	Much improved three months later.	
52	Tuffier: Sem. Med., 1895, p. 447.	Male, 25	Tuberculosis localized to right apex. . . . .	Tubercle bacilli found in sputum.	No	Apex with 2 cm. of healthy lung; wound closed without drainage.	Discharged cured on ninth day.	Living 4½ years after operation.
53	Quinke: Mitteil aus deu Grenzgeb. der Med. u. Chir., 1896, vol. i, p. 234.	Male, 46	Cavity of right upper lobe. . . . .	Symptoms of advanced pul. tuberculosis; signs of a cavity.	No	Application of zinc chlorid to produce adhesion; 8 da. later cautery; no cavity found; 8 days later enlargement of wound; removal of 1st rib; cautery; no cavity found; week later removal of second rib; cavity opened.	Improvement of patient.	Death three years later. . . . .
54	Bier: Cited by Quinke, Ibid.	Male, 23	Large cavity in right apex. . . . .	Signs of a cavity. . . . .	Yes	Subperiosteal resection; second and third ribs; a year later resection of second rib, cavity opened; cautery; resection, third, fourth, fifth and sixth ribs; drainage.	Retraction of chest wall during next few wk.; symp. diminished; general emphysema at once.	Death 2½ hours after second operation.
55	Franko: Ibid, p. 658 . . . . .	Female, 21	Cavity in right upper lobe. . . . .	Signs of cavity; sputum cont. tubr. bac.	Yes	Resection of second rib; cautery; tampon of iodoform gauze in cavity.	Great improvement . . . . .	Death 17 mos. later. influenza; fistula only 1½ cm. deep.
56	Bozzolo: Gazz. degli Ospedali, July 1, 1898.	Male, 36	Cavity in right lung. . . . .	All the symp. of tubr., but no tubr. bac.	1 No, 2 Yes	Pneumotomy followed by syncope; 2 months later again incised; 2 cavities drained.	Recovery . . . . .	
57	Tait and Abrams: Med. News, 1898, p. 263.	Male, 7	Acute tuberculous cavity in left lower lobe; later, signs of cavity in right apex.		Yes	Pneumotomy and drainage; 1 yr. later resection of second, third, fourth and fifth ribs; pneumotomy; drainage.	Great improvement after first operation remained well 1 yr.	Death 28 hours after second operation.
58	Malbot: Arch. provin. de Chir., 1898, No. 12, 1899, Nos. 1 and 2.	Male, 29	Cavity in left upper lobe; tuberculosis of right lung.	Symptoms of cavity; symp. of advanced tuberculosis.	Yes	Cavity opened and drained; water, potass., permang., tinct. Cl <sub>2</sub> sol. 1:15 for cleansing and cauterizing.	General improvement . . . . .	Wound closed in 3 months' time; apparent recovery.
59	Mayo: Northw. Lancet, 1898, xviii, 441.	Female, 38	Cavity of left lower lobe. . . . .	Signs of a cavity . . . . .	Yes	Incision at posterior, anterior and axillary line; cavity opened and drained for 3 wk.; 3 ribs resected.	Great improvement at first.	Death after 5 months, from spread of disease.
60	Karowsky: Verträge d. deutschen Ges. f. Chir., 1898, xxvii, pt. 2, 285.	Female, 30	Cavity in lower left lobe; pleurisy.	Signs of a cavity; hectic fever, etc.	Yes	Resection of eighth, ninth, tenth and eleventh ribs; cavity ruptured into pleural cavity; cheesy material curetted from pleura and lung cavity; drainage; curettement several months later.	Improvement for several months.	Since second operation disappearance of all symptoms.
61	Salomoni: Cong. of Ital. Surg., Oct., 1898.	Male, 22	Cavity in lower lobe of left lung; empyema.	Tubercle bacilli discharge from empyema fistula.	Yes	Resection of ribs (seventh-eighth); pleura opened with cautery; 2 cavities in lung below; purulent collection; curettement; drainage.	Improved quickly . . . . .	18 months later condition fair; right lung good; one fistula remains over left lung.
62	Straspeko: Ann. of Russian Surg., 1899.	Female, 25	Tubr. cavity had opened externally; it appeared to be cavity of ribs.			Cavity opened; curetted with spoon; tamponed.	Improved. . . . .	Healed soon. . . . .
63	Straspeko: Ibid. . . . .	Male, 36	As above. . . . .			Identical procedure. . . . .	Improved. . . . .	Healed soon. . . . .
64	Turban: Berl. Kl. Woch., 1898, xxxvi, 438.	Male, 21	Infiltration of right upper lobe; almost entire left lung is one cavity.	Typical symptoms and signs.	Yes	Removal of portions of fourth to seventh ribs; closure of wound; primary union; wound reopened after 2 mo.; resection of portion of sixth to ninth ribs; destruction of periosteum; lung much smaller.	Prim. incre.; second, decre. of symp., with cavity contracted of lung; tert. incre. of cavity; considerable improvement of symptoms.	Three years after second operation alive; condition no worse than after operation.
65	Tuffier: Bull. et Mem. d. l. Soc. d. Chir. d. Paris, 1890, xxvi, 342.	Female, 30	Pulmonary gangrene; sputum contains tubercle bacilli.			Incision; pneumotomy; 8 cm. of lung resected; drainage.	Perfect recovery after six months; fistula persists; no tub. bac.	Apparently cured. . . . .
66	Ferguson: Med. News, 1900, i, 405.	Male, 27	Abscess beneath pectoralis major secondary to tuberculosis of lungs and tubercular osteitis.	Good; no signs of cavity.		Three operations. 1. Opening of abscess; drainage. 2. Resection third and fifth ribs; packing with iodoform gauze. 3. Resection of a piece of tuberculous lung; packing with iodoform powder twice a week for month.	No improvement after first two operations; remarkable improvement after the third.	
67	Sarret: Deutsche Med. Woch., 1901, p. 103.	Female, 40	Large cavity in right upper lobe.	Fever; hemoptysis; cachexia; signs of a cavity.	Yes	Resection of second rib; pleurotomy; pneumotomy; cavity opened extensively.	Improvement; fever & hemoptysis ceased.	Death 5 mo. after operation, due to an intercurrent pneumonia.
68	Wills: Jour. Am. Med. Ass'n, 1901, i, 19.	Male, 45	Cavity in lower lobe of left lung; consolidation of left apex.	Typical symptoms of 3d stage of disease.	Yes	Resection sixth rib; pleurotomy; drainage; operation not continued because of man's bad condition. Nine days later spontaneous rupture of cavity into wound.	Gradual improvement.	21 months later no cavity; had gained 75 pounds; apparently well.
69	Wills: Ibid. . . . .	Male, 30	Cavity in lower lobe of right lung; infiltration of both apices.	As above . . . . .	Yes	Resection of portions of eighth and ninth ribs in front of their angles; pleurotomy; drainage. Six days later pneumotomy; drainage; irrigation with formalin.	Improvement. . . . .	Died 6 months later. . . . .
70	Maffert: Quoted by Murphy, Journ. A. M. A., 1898, ii.	Male, 19	Chondro-sterno-costal tuberculosis and tuberculosis of lower lobe of left lung.	Symptoms of purulent pleurisy; no sign of a cavity.		Resection sixth rib in axillary line; discharge of pus containing bacilli; lavage; drainage.		Death 1 month later. . . . .
71	Porritt: Lancet, 1892, vol. ii, p. 1532.	Male, 65	Cavity right upper lobe. . . . .			Second and third ribs removed; anterior and posterior.	Improvement. . . . .	Death 3 years later. . . . .
72	Porritt: Ibid. . . . .	Female, 15	Cavity left upper lobe. . . . .			First, second, third and fourth ribs removed; posteriorly.		Death second day. . . . .
73	Porritt: Ibid. . . . .	Male, 47	Cavity left upper lobe. . . . .		Yes	Second, third and fourth ribs removed; anterior to axilla.		Death pneumonia, within few days.

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ALBERT.—Results prove that pneumonotomy should not be done in tuberculosis and that pneumonectomy is never advisable in that disease.

HEITLER.—Tubercular cases of any description are not operable by pneumonotomy or pneumonectomy.

HEYDWEILLER.—Pneumonotomy is useless, since the disease is not cured by operation and the patient subsequently dies. Conclusions based upon forty-two cases, with twenty-three deaths, fifteen improvements and four relative cures.

RICKETTS.—After operation in tubercular cases 60 per cent. recover. In 306 cases of pneumonotomy for various causes, tubercular and non-tubercular, 71 per cent. recovered, showing that surgery is beneficial.

BULL.—In rare cases of tuberculosis, where a large cavity is the predominating condition, the cavity may be laid open with a view to improvement of the patient and as a palliative.

KOCH.—Pneumonotomy would be helpful in strictly localized tuberculosis of the lung, a condition which is of rare occurrence.

KRECKE.—Operation is indicated when the cavity is single and there are symptoms of septic absorption.

LESER.—The excavation, especially if it is large, should be opened through the chest wall to permit purulent contents to escape. This operation should especially precede the use of Koch's tuberculin, since after tuberculin is used the discharge is too great to be removed by expectoration.

WILLS.—Emphatically favors pneumonotomy in the early stages as good conservative surgery, saving life and giving comfort.

GARRE.—Pneumonotomy is advisable in rare cases.

KUMMEL.—Operative interference is indicated when the cavity can be definitely located and stagnating conditions produce grave symptoms.

RICHEROLLE.—Pneumonotomy in very large tubercular cavities is allowable, but not if they are numerous.

ROCHIELT.—Operation is justifiable if the symptoms are severe, or hemorrhage frequent, or the cavity is superficial. When the process is active and the temperature high, no operation.

BLOCH.—Operation favorable in hemorrhage of the lung.

SARFERT.—Little encouragement for operation, yet is



sometimes advisable, especially if the disease is circumscribed and the symptoms not severe.

POIRIER AND JONNESCO.—Have collected many cases. Favor operation, especially in the cases where the abscess forms in the lower lobe.

FOWLER.<sup>13</sup>—Difficult to outline the exact cavity and to know when there are adhesions. The question of adhesion is a very important one as regards pneumothorax. If the disease is quiescent, operation not advisable; if the disease is advanced, it is useless.

DA COSTA.—Operation is unjustifiable if the cavities are multiple and not circumscribed, or if the disease is progressing. Advise against pneumonectomy.

SONNENBURG.—Has abandoned the operation as useless, although one of his patients lived five years. Only those cases operable, where the disease is circumscribed, the cavity favorably located, the patient fairly strong and without hectic fever. The opening should be free.

NEVE.—Successful case of drainage and application of creosote locally.

MANCLAISE.—Operation limited to circumscribed tuberculosis, without surrounding infiltration.

SALOMONI.—Operation is of value in single cavities, but in spite of a few fortunate results is not to be commended except occasionally.

TUFFIER.—Favorable to the operation, and yet he acknowledges that in only one case was he able to reach the focus at the time of the operation. Injections have proven themselves valueless. Pneumonotomy relieves symptoms if free drainage is secured.

TURBAN.—Operation advisable if one lung is healthy, even if the other is seriously diseased.

MURPHY.—In advanced disease pneumonectomy is inadvisable, and in the early stage patients will not consent. Pneumonotomy gives a chance for free drainage and lessens the septic symptoms.

WOOD.—Incision and drainage of a tubercular cavity is indicated when there is limited tubercular involvement and when the patient is suffering from the septic effects. These symptoms are ameliorated by pneumonotomy, and while a case is occasionally cured the majority die. Pneumonectomy is unjustifiable.

FERGUSON.—Drainage and injection of iodoform give good results.



EWALD.—Operation is advisable.

CASINI.—A circumscribed tubercular process may be attacked by surgical interference and the cavity treated with as much reason as one in a tubercular bone. A single cavity, even though it is deep, should be drained to prevent general infection.

FABRICANT.—Pneumonotomy is advisable when the symptoms of infection from the cavity overshadow all others.

#### CONCLUSIONS AS TO HUMAN SURGERY.

1. With improvement in technic pneumonotomy will become a practicable operation, even in cavities at the apex. The operation would be especially helpful in the early period of cavity formation, but it is exceedingly difficult at this stage to obtain the consent of the patient, since hygienic and dietetic methods of treatment often result in cure.

2. In advanced cases, both tubercular and streptococcic infection are often present; the cavities are usually multiple and the operation can not cure. It may be employed, however, as a palliative to cough, hemoptysis and sepsis.

3. In abscess of the lower lobes, following pneumonia or pleurisy, whether tubercular or not, incision and drainage is to be recommended in any stage.

4. Pneumonectomy in our present stage of surgical and diagnostic skill is not advisable in tuberculosis.

5. With improved technic tubercular foci will in the future be eradicated, as we now eradicate tuberculosis in joints and other tissues. An efficient and certain method of producing strong adhesions between the two layers of the pleura at the site of the disease is the most important step in this technic.

6. The careful and methodical application of auscultation, percussion and the *x*-ray for the accurate locating of the diseased focus, is also an important factor in securing a safe operation.

7. Pneumothorax is so serious a menace to life that in all operations on the lung, an artificial respiration apparatus, like the Fell O'Dwyer or Matas instrument, should be at hand, together with a full jar of oxygen.

#### EXPERIMENTAL TECHNIC AND RESULTS.

For the primary induction of tuberculosis in the dog, injection with a long hypodermic syringe was made into

the lung in the third interspace on the right side, one and one-quarter inches from the midsternal line, under thorough antiseptic precautions, and the results awaited.

The material used for infection was from  $2\frac{1}{2}$  to  $3\frac{1}{2}$  c.c. of a growth of tubercle bacilli, ground up in a sterile tube with sterilized water until in appearance and density the mixture was equal to a twenty-four-hour culture of typhoid. This made a white, thin, milky fluid, which flowed easily from the hypodermic.

For the secondary operation the animal was always given a full dose of morphia (one-quarter to one and one-half grains) an hour before etherization. The area operated on was first shaved, scrubbed with soap, then with alcohol, ether and bichlorid or turpentine and surrounded with sterile towels. Instruments and hands were thoroughly sterilized and all preparations made as in human operations.

The ether was administered by cone, as chloroform will kill, and a Fell O'Dwyer artificial respiration apparatus kept on hand, by the use of which life can be maintained in many cases where otherwise the animal will die. As the introduction of the tube through the mouth is too risky to the operator, it is better to open the larynx when necessity arises and insert the tube into the trachea, the inflation of the lung then being slowly and regularly maintained.

Silkworm suture; catgut drainage, or gauze; sterile gauze dressing; plaster of paris bandage. May dress with iodoform and collodion or with turpentine. In ligating lobe of lung, kangaroo tendon or chromicized catgut. Dogs were usually redressed on the second or third day, and, if clean, were allowed to go for several days. Whenever suppuration was found, dressed every two days, the wound being washed with bichlorid.

In some cases the dogs after injection of tubercle began to lose flesh at once, and in a month the loss was from two to four pounds; others developed a cough, but as the sanitary conditions in confinement and in the cellar were unfavorable, progress was, of course, naturally active. In spite of this several cases did not show any tubercular lesion even weeks after the injection. Many of the dogs showed foci of tuberculosis through the lobes of both lungs, the infiltration in many cases being as great in the opposite lobe as in the one injected. The mediastinal glands were usually found implicated. The lung tissue intermediate to the foci was usually

- normal. In a few cases the lower lobe was densely infiltrated with tubercular pneumonia. In none of the cases were the other organs affected nor the bones. One dog only died from tuberculosis (No. 3), living from September 2 to November 4. In three or four cases there was a localized abscess in the lung apparently not from the injection, but from the infection through the bronchi.

The dangers of the operation are illustrated by the fact that 4 died during the operation from pneumothorax; 2 others within thirty-six hours, one from hemorrhage into the bronchi from pleural suture, one from sepsis of lung abscess, from cutting off of blood supply of lung tissue by preliminary suture of pleura; 2 cases of pneumonectomy died of purulent pleurisy.

The dyspnea from pneumothorax during operation was always greatly relieved by grasping the lung and holding firmly in place. Incision into the lung of a dog, if sutured, will recover almost certainly, and also excision of a wedge-shaped piece. Puncture and incision of the lung recover. An entire lobe can be safely removed. A strong dog will probably survive removal of entire lung. Excision of diseased lung, of course, will not interfere so seriously with respiration as would the removal of a healthy lung. The lung should not be ligated en masse, but in small portions; the bronchus and its vessels should be ligated independently. The open end of the bronchus should be sutured.

#### DEDUCTIONS FROM EXPERIMENTS.

The production of adhesions is a most important part of the operative procedure. If these can be secured, either artificially or if they are present from the disease itself, the operation is not more serious than many major operations.

In the human being the position of the abscess can be much more definitely fixed than in the dog by auscultation, percussion and the *x*-ray. Operation, therefore, becomes one of greater certainty. If slight adhesions only are found, immediate stitching of the lung to the walls around the margin of the opening, while not avoiding pneumothorax, may escape pyothorax. If pneumothorax occurs, the most speedy method of relief is that of dragging the lung into the opening and fixing it, thus giving greater action to the opposite lung. Excision of the diseased area would be the best opera-

tion, provided the entire tuberculous portion could be definitely removed, a condition which at present does not seem possible. In dogs even a collapsed lung becomes functionally active in a few days after excision of a portion.

EXPERIMENT\* 1.—Dog, 15 pounds. Injection 3 c.c. emulsion tubercle bacilli, right upper lobe, Aug. 26, 1901;  $\frac{3}{4}$ -grain morphia given previously. September 2 no ill effects; September 5 small abscess circumscribed at point of injection; September 20 loss of  $1\frac{3}{4}$  pounds. Still losing flesh.

*Operation.*—Thirty-ninth day, one-half grain morphia given 20 minutes previous to etherization. Incision  $2\frac{1}{2}$  inches long, third interspace. With a long curved needle, silk ligature was carried through intercostal space, penetrating lung and brought out  $1\frac{1}{2}$  inches distant. Tied sufficiently firmly to bring visceral pleura in contact with parietal, intending to place similar one in fourth interspace and cross sutures at ends of these two, in shape of parallelogram to produce adhesions. Immediately after the passing of the first suture, however, bloody froth appeared at the mouth, respiration became difficult and in spite of the injection of 1/60 grain of strychnin and forced artificial respiration, the dog died quickly.

*Postmortem.*—Small coagulum in right pleural cavity; no other blood or fluid in pleura; no pneumothorax. Needle had evidently punctured a large pulmonary vein, and the bronchi were filled with blood. Air probably entered the veins from the perforated bronchi, as the heart was flabby and contained frothy blood, especially in the right auricle. Upper lobe entirely consolidated with tubercle; the two lower lobes normal, but the infiltrated lobe was yellow. Firm adhesions were present from the site of the injection to the apex, one and one-half inches wide; all other portions of lung free. Posterior mediastinal lymphatic glands enlarged to size of pigeon eggs; one anterior mediastinal gland also infiltrated. Abdominal organs healthy. One mesenteric gland enlarged.

EXPERIMENT 2.—August 26. Dog. Weight 29 pounds. One and one-half grains morphia given; 3 c.c. emulsion tubercle bacilli injected into right upper lobe. Puncture sealed with gauze and collodion. September 27 loss of  $7\frac{1}{2}$  pounds. October 1, cough and expectoration; latter could not be obtained for microscopic examination.

*Operation.*—October 3. Morphia,  $\frac{1}{2}$ -grain, 20 minutes before etherization. Fourth rib resected; accidental opening in

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\* The experiments detailed were conducted at the Pepper Clinical Laboratory of the Hospital of the University of Pennsylvania, with the assistance of Drs. George M. Purves and Eugene Lindauer, without whose help they would have been impossible.



the pleural cavity; adhesions were found slight; parallelogram suturing; pneumothorax was marked, but did not give extreme dyspnea. Death 36 hours later.

*Postmortem*.—Right lung entirely collapsed, 3 drams bloody serum in right pleural cavity. No large tubercular area of consolidation, but over entire pleura were numerous yellow foci, and in the upper lobe of the lung some yellow foci, which had not broken down. Anterior and posterior mediastinal glands enlarged, size of lima beans. Left lung partially collapsed, but upon the parietal pleura and the surface of the lobes of the left lung were nodules similar to those in the right. In the right lung there were no adhesions to the pleura at the site of the injections, but there were firm adhesions over the area of half an inch at the apex. No other adhesions in either right or left. Other organs healthy.

EXPERIMENT 3.—September 2. Injection  $1\frac{1}{2}$  inch to right of mid-sternal line, 3.5 c.c. emulsion tubercle bacilli. No cough, but progressive loss of weight, with weakness. Died November 4. Had cough and expectoration, but not enough to collect for microscopic examination.

*Postmortem*.—Markedly emaciated; right pleural cavity small amount of bloody serum; apex of right upper lobe consolidated with firm adhesions to ribs  $1\frac{1}{4}$  inches in diameter; beneath these was a cavity in the lung substance an inch in diameter connected with the pleural cavity; space contained thin tubercular pus. In lobe of right lung, two similar tubercular consolidations; posterior mediastinal glands enlarged; anterior glands size English walnut; other organs healthy.

EXPERIMENT 4.—September 9. Weight, 34 pounds. Morphia  $1\frac{1}{4}$  grains; injection of 3.5 c.c. tubercle bacilli emulsion. As there was no loss of weight, October 18 additional 3 c.c. injected in the same area.

*Operation*.—November 4; 3 inches of rib excised; area around point of injection sutured off in a parallelogram with silk carried through the substance of the lung, and sutures tied merely to bring surfaces in apposition. Dressed with sterile gauze, plaster of paris outside. Owing to an error, pneumonotomy was not done, as it should have been on the second day. Dog lost flesh and died November 29. Sinus at point of wound; right lung was strongly adherent as low as the third rib; the upper lobe condensed, but no positive tubercle foci; small abscess at the point of operation; glands not involved.

EXPERIMENT 5.—October 8. Weight 27 pounds; morphia,  $1\frac{1}{4}$  grains; injection 4 c.c. tubercle bacilli emulsion into right lung. November 2, dog greatly emaciated, scarcely able to stand.

*Operation*.—November 5. Lung sutured to wall as before. Wound made in pleura and dog died speedily, in spite of arti-



ficial respiration with Fell O'Dwyer apparatus; strychnin and digitalis.

*Postmortem.*—No adhesions nor effusion on either side. Both lungs evenly infiltrated with yellow tubercular nodules varying in size from a pin to that of a bean, a few of them breaking down in the center; no deposits in pleura nor in abdominal organs.

EXPERIMENT 6.—November 7, 18¾ pounds; 1 grain morphia given; ether; 2 in. incision over third rib. Visceral and parietal layers of pleura approximated by silk sutures, plaster of paris with the intention of producing adhesions before making the tuberculin injection. Next day 3 c.c. tubercle bacilli emulsion injected into the lung. November 29: dog has lost flesh rapidly.

*Operation.*—Previous incision healed by first intention except at lower angle where sinus persisted and through which much air entered; sinus leads into the lung through second interspace; acute pneumothorax followed the incision into pleura and dog died in five minutes.

*Postmortem.*—Right lung collapsed. Strong adhesions along lower margin of second to fourth rib, which could not be torn with moderate pressure of finger. The longitudinal sutures had evidently produced adhesions, but the transverse sutures had not, as they had been passed beneath rib from the second to third interspaces; lung not infiltrated.

EXPERIMENT 7.—November 12, 11 pounds, one-half grain morphia; ether; longitudinal sutures, first and second intercostal spaces 1¼ in., united by cross suture at ends around second rib; 2 c.c. emulsion of tubercle bacilli injected at end of operation.

*Operation.*—December 28. Incision through old scar, third rib resected subperiosteally. When pleura was opened acute pneumothorax developed, with great dyspnea; rapid tracheotomy performed; Fell O'Dwyer artificial respiration inflation practiced, with success in reviving; upper lobe of lung pulled into incision and sutured with catgut; projecting portion ligated with silk and cut off; wound closed with drainage; tracheal wound closed; sterilized gauze and plaster of paris bandage. Next day respiration 40; plaster stained with offensive discharge; lung slipped from its anchorage; collapse from the pneumothorax; drainage tube inserted; pleural cavity washed with borie acid solution.

*Postmortem.*—January 2. Right pleural cavity infected; yellow pus; adhesions at apex, but no consolidation in either lung; lung had slipped from anchorage; no evidences of hemorrhage; tracheotomy wound healed first intention.

EXPERIMENT 8.—December 12. Preliminary suturing of lung to chest wall with silk suture; 3 days later injection 3 c.c. tubercle bacilli emulsion; 11 days later, cough.

*Operation.*—January 24. Third rib resected subperiosteally  $1\frac{1}{2}$  in.; pleura was opened; breathing became labored, but not to an extreme degree. Tracheotomy done and artificial respiration apparatus used; dog revived. Adhesions were firm, but did not completely surround the line of incision. Lung pulled into opening and sutured to chest wall. Packed with sterile gauze. January 29, dog dressed. Air escaped from site of sutured lung.

*Second Operation.*—February 5. Second rib excised. When pleura was opened adhesions only partial, and pneumothorax followed; as the lung was adherent, symptoms were not serious; palpation of lung failed to find any consolidated area or cavity. Wound was packed, and a second injection of tubercle bacilli emulsion made into upper lobe. March 12: No apparent loss in weight, dog apparently normal.

*Third Operation.*—Lung exposed and palpated, but no cavity found, although incisions were made in one or two directions into the lung. Hemorrhage checked by packing with gauze. Died 24 hours after third operation.

*Postmortem.*—Upper lobe right lung adherent opposite second and third ribs; firm, anteriorly to the extent of  $1\frac{1}{2}$  in. Upper lobe shows mark of incision; pleural cavity contained much red clotted blood, but was otherwise normal; no tubercular infiltration in any portion of right or left lung; abdominal organs healthy.

EXPERIMENT 9.—December 12. Small dog. Pleural surfaces sutured as before; 2 c.c. tubercle bacilli emulsion injected in right upper lobe. January 15: no emaciation. Eating; drinking; lively.

EXPERIMENT 10.—Preliminary suturing of pleural surfaces. December 14, 3 c.c. tubercle bacilli emulsion injected.

*Operation.*—January 14. Preliminary incision made over trachea, not dividing rings. Incision, line of previous scar. Preliminary sutures of silk found. Fourth rib excised; adhesions around area firm; lung opened; penetration with grooved director; small amount of pus evacuated, but in spite of completed tracheotomy and the use of Fell O'Dwyer artificial respiration apparatus, dog died.

*Postmortem.*—Many adhesions beneath the second and fifth ribs, but no area of consolidation and no nodules were found in either lung. The upper lobe of the sutured lung was very friable, and broke down readily under the fingers, a condition that had been discovered before death, probably due to the cutting off the blood supply by the sutures.

EXPERIMENT 11.—March 18. Preliminary exposure of trachea, but tube not opened. Third rib excised. Acute pneumothorax as soon as the pleura was opened, but symptoms not severe. Lung seized with forceps and pulled into the opening; improvement in symptoms; lung anchored to margin

of wounds by interrupted silk sutures; lung ligated, and portion removed; stump sutured to chest wall.

EXPERIMENT 12.—April 4. Two injections previously of 2.5 c.c. tubercle bacilli emulsion. Has not lost weight. Excision of one inch third rib. Upper lobe seized as quickly as possible and dragged into the wound through chest wall. Dyspnea was immediately greatly lessened. Artificial respiration other than manual not required. Lung sutured to margin of wound, ligated with silk and cut away. Drainage with gauze. April 24, apparently perfectly healthy and eating and drinking normally. Killed by chloroform. Small narrow sinus presented leading to third rib; strong adhesions at site of suturing, 1 in. in each direction; small area of infiltration  $\frac{1}{2}$  in. in diameter adjacent to site of suturing. Consolidated, earuified and sinking in water. Remaining portion of lung had regained its function, was erepitant and floated. Few adhesions in left pleural cavity. Abdominal and other organs healthy.

EXPERIMENT 13.—April 5;  $\frac{1}{2}$ -grain morphia, hypodermic ether. Preliminary incision over trachea without opening the tube. Subperiosteal excision third rib. On opening pleura, pneumothorax and dyspnea severe, but as soon as lobe of right lung was grasped and dragged forcibly into the wound, improvement occurred. Artificial respiration not required. Lung sutured to chest wall with silk sutures tight, so as to prevent all air from entering pleural cavity; lung ligated and cut off. Incision in throat closed. Wound drained; sterile gauze; plaster of paris. April 24, killed with chloroform. Small sinus leading to silk suture. Right pleural cavity strong adhesions 1 in. from point of suturing; lower and posterior parts of upper lobe normal in color and appearance; erepitating on pressure and floating in water; right lower lobe normal; in the area of excision there was consolidation; was non-erepitant; remainder of upper lobe had evidently regained its function.

EXPERIMENT 14.—Trachea exposed. Third rib excised; acute pneumothorax with dyspnea relieved by dragging lung into the opening and holding it with hemostatic forceps. Trachea incised and artificial respiration kept up with bellows, but death occurred in about a minute and a half after pleura had been opened.

EXPERIMENT 15.—Pneumonectomy; suturing of lung. Small dog. Incision in left side between fifth and sixth ribs; marked collapse when pleural cavity opened; ether then suspended; lower lobe caught with blunt forceps, pulled into the opening and sutured to the wall with chromicized gut. Muscle sutured with silk; dressed with collodion; dyspnea great, but dog walked in ten minutes and the following day had apparently suffered nothing from the wound. Ninth day, superficial stitches gave way and the wound opened; adhesions to the

wall seemed firm and strong; incision was made into lung substance one-third inch deep; hemorrhage controlled by packing; drainage. Dog killed at end of 4 weeks; wound entirely healed; had not lost his appetite since second day; firm adhesions to the wall; pleura smooth and healthy; effusion.

EXPERIMENT 16.—After laying bare the intercostal muscles chromicized catgut suture carried with curved needle through the lung and was drawn firmly against the parietal pleura. Tenth day pneumonotomy. Adhesions seemed firm, but by an accident loosened at one side, the pleura became infected, causing the death of the dog in two days. Pleura contained a large amount of fetid pus and the lung had collapsed.

EXPERIMENT 17.—Incision fifth interspace. Endeavor made to produce adhesions of the pleura by Paquelin cautery; failure. Dog killed with chloroform on the following day.

EXPERIMENT 18.—Ether. Opening seventh interspace, lung turned into the wound. Anchored, ligated and cut away. Dog killed 35 days later. Soft parts entirely healed. Lung firmly adherent to thoracic wall at point of suture, otherwise restoration of function good.

#### SUMMARY OF TABLES.

Pneumonotomy of apex 34; recoveries 20 (of whom 2 died in from 3 months to 3 years later); deaths, 14; operative recoveries 59 per cent. Lower lobes 20; recoveries 15 (of whom 2 died within 15 months); speedy deaths, 5; operative recoveries, 75 per cent. Location of cavity not mentioned, 7; recoveries, 4; deaths, 3; operative recoveries, 57 per cent. Total pneumonotomies 61; recoveries, 39; deaths, speedy, 22; deaths later, 10; operative recoveries 64 per cent.

Pneumonectomies, 6; recoveries, 4; operative recoveries, 67 per cent. (Nos. 10, 11, 40, 48, 52, 66. See tables).

Excision of ribs to produce collapse of chest and lung, 8 operations on 7 cases; recoveries 5 (one died 3 years later); deaths, 3; operative recoveries, 63 per cent. (Although the cases are few, yet the percentage of recoveries is no better than when lung was entered.)

Total operations for tubercular cavities 75, upon 73 cases, with 64 per cent. of operative recoveries. It is impossible to secure the final result in these cases, and even if secured, it would be difficult for faithful comparison to set aside 73 cases of precisely equal severity; moreover, the results that would have been obtained from medical treatment in these 73 cases can be only conjectured. The presumption is that they were of serious type, otherwise they would not have been subjected to operation, consequently the ultimate death rate would have been very high under any form of treatment.



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\* This contains references to all the papers of ancient literature, as well as most papers up to 1874.